The Journal of Animal & Plant Sciences, 27(1): 2017, Page: 20-27
ISSN: 1018-7081

GENETIC EVALUATION OF LAYING TRAITS IN IRANIAN INDIGENOUS HENS USING UNIVARIATE AND BIVARIATE ANIMAL MODELS

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ABSTRACT

The present study was carried out with the aim to estimate genetic parameters as well as evaluating genetic improvement in Iranian native chickens to assess the effectiveness of selection programs performed in Azerbaijan native fowl breeding station. The data on pedigree and performance was collected through five consecutive generations consisted of 4400 hens and roosters. Considered traits were body weight at week 12 (BW12), total number of eggs laid during the first 12 weeks after flock maturity (EN), mean egg weight at 28, 30 and 32 weeks (MEW) and age at sexual maturity (ASM). The (co) variance components, heritabilities, correlations between traits as well as breeding values were estimated through univariate and bivariate animal models using WOMBAT software. Heritability estimates for BW12, EN, MEW and ASM, using four different univariate animal models, were 0.25±0.08, 0.18±0.05, 0.24±0.03 and 0.43±0.07, respectively. A bivariate animal model was applied to estimate genetic correlations between traits. Genetic correlations were in a range from-0.10 to -0.63. The highest and lowest genetic correlation were between ASM and MEW (0.30± 0.06) and ASM and EN (-0.63± 0.02), respectively. Regression coefficients of average breeding values on generation number were positive and significant for BW12 and EN, indicating positive trend that confirmed genetic progress in these traits. However, MEW as well as ASM responded negatively to genetic improvement.

Key words: Heritability, Genetic correlation, Genetic trend, laying traits, Animal model.

INTRODUCTION

Iran has various regions with extremely different environments and there are several indigenous poultry breeds, which have been adapted to those local climatic conditions through long-term natural selection (Mohammadabadi *et al.*, 2010). The most important native fowls of Iran are the Mazandaran, the Fars, the Isfahan and the Azerbaijan (Kianimanesh *et al.*, 2001c). These native breeds of chickens play an important role in rural economies for most of the rural farmers and village households. Despite their low growth rate and low egg production, there has been always an interest and attention among farmers and consumers because they are generally better in disease resistance and could maintain higher levels of performance under poor nutrition and high/low environmental temperatures compared to commercial strains under village systems. In addition to that, the desirable taste and flavor of their eggs and meat are weighty matters that cannot easily be dispensed with (Horst, 1989; Haunshi *et al.*, 2010).On the other hand, these invaluable and dwindling genetic supplies are under risk of extinction and need to be protected. The population of native fowls in Iran, decreased from 30 million in 1960's to about 12 million in 1980's and they participate less than 10% of total poultry meat and egg productions of the country. One of the best ways to protect the native fowls from extinction is to support them through an elaborated genetic improvement program (Kianimanesh *et al.*, 2001c).For this purpose, during recent years, there has beenabroadattention among researchers and authorities on native chickens. Accordingly, under a national breeding and conservation project, some breeding stations were established in various provinces of Iran, including Mazandaran, Fars, Isfahan and West Azerbaijan (Kianimanesh *et al.*, 2001c).

This work was a part of a national project conducted under Iranian Agriculture Ministry and Animal Science Research Institute in more than six breeding centers throughout Iran including the Native Chicken Breeding Center of West Azerbaijan province. In fact, the long-term and ultimate objective of this project was genetic improvement and conservation, as well as the possibility of developing a new commercial line from these local chickens.

According to Kianimanesh *et al.* (2001b) and Kamali *et al.* (2007), the most important traits for improving the genetic status of Iranian native chickens are body weight at 12 weeks of age, number of eggs, egg weight and age at sexual maturity. Therefore, the main objective of this study was to estimate variance components, genetic parameters and breeding values as well as predicting genetic trends of these traits over five primitive generations in West Azerbaijan native fowls.

These parameters, as a useful source of information, could provide a valuable tool for conducting any breeding program to fulfill the goals of the aforementioned national project.

MATERIALS AND METHODS

Data: The Native Chicken Breeding Center of West Azerbaijan province was established in 1988, and within the years from 2001 to 2014, eleven generations of selection were recorded. The data file considered in this study, consisted of 4400 pedigree and performance records which collected from five preliminary generations (generations one to five) to evaluate genetic parameters of four recorded traits including BW12 (body weight at 12 weeks of age), EN (total number of eggs laid during the first 12 weeks after flock maturity, when 5% of the flock is in egg production), ASM (which determined and recorded as age at which hens laid their first egg), and MEW (mean egg weight at 28,30 and 32 weeks of age).

During the first years, a concerted effort was made to detect and purchase native chickens from far the rural areas across the Azerbaijan province based on their phenotypic properties and kept in a quarantine farm. After practicing quarantine procedures, about 488 birds of both sexes were remained and formed the base population. The first generation was created by random mating within the base population. Day-old chicks were wing-banded. Parents of each generation were selected among pedigree file and performance records, with an average selection proportion of about 40% for hens and 5% for cocks and the mating ratio was 1 sire to 8 dams. Birds were selected as parents of the next generation in two steps. In the first step, females and males were selected based on their BW12. After 20 weeks of age, hens were transferred into individual cages and their egg production was recorded for 12 weeks. In the second step, hens were selected based on their ASM, EN and MEW. Moreover, roosters were selected based on the performance of their sisters. The selected males and all females were transferred to the layer houses and kept in floor pens. Pens were fitted with trap nests to facilitate full pedigree recording.

Statistical analysis: Univariate and bivariate animal models (Henderson 1984) were used in order to estimate variance components, genetic parameters and genetic correlations among traits. To choose a proper operational linear model approximating true model, all fixed effects and covariates related to studied traits were considered and selected based on F statistics using a backward elimination procedure to specify the most effective elements in models. The significance of these effects were all statistically significant ($P<0.05$).Fixed effects were a combination of generation and hatch (five hatches in each generation), and sex. The effects of body weight at sexual maturity and mean egg weight were taken into account as covariate effects for BW12. However, for EN, MEW and ASM only body weight at sexual maturity considered as a covariate effect.

The following four different univariate animal models in linear notation were used to estimate variance components and heritabilities:

Model 1 (BW12): $y_{ijk} = \mu + S_i + GH_j + A_k + e_{ijk}$
Model 2 (EN): $y_{ijkl} = \mu + GH_i + BSM_j + MEW_k + A_l + e_{ijkl}$
Model 3 (MEW): $y_{ijk} = \mu + GH_i + BSM_j + A_k + e_{ijk}$
Model 4 (ASM): $y_{ijk} = \mu + GH_i + BSM_j + A_k + e_{ijk}$

Where:

In model 1, y_{ijk} is the body weight record of the k^{th} progeny ($A_{k=}$Random effect) with the j^{th} hatchery-generation combination ($GH_{j=}$fixed effect) and i^{th} sex ($S_{i=}$Random effect). In model 2, y_{ijkl} is the egg number record of thel^{th}progeny (A_l=Random effect) with the k^{th} record of mean egg weight ($MEW_{k=}$covariate effect), j^{th} body weight at sexual maturity record ($BSM_{j=}$ covariate effect) and the i^{th} hatchery-generation combination ($GH_{i=}$fixed effect). In model 3, y_{ijk} is the mean egg weight record of the k^{th} progeny ($A_{k=}$Random effect) with the j^{th} body weight at sexual maturity record ($BSM_{j=}$ covariate effect) and the i^{th} hatchery-generation combination ($GH_{i=}$fixed effect). In model 4, $y_{ijk}$is the body weight record of the k^{th} progeny ($A_{k=}$Random effect) with the), j^{th} body weight at sexual maturity record ($BSM_{j=}$ covariate effect) and the i^{th} hatchery-generation combination ($GH_{i=}$fixed effect). In each models e= random error and μ= common mean of performance record related to studied trait. COV(u,e)assumed to be zero.

In addition, correlations among traits were estimated by bivariate animal model. The procedure used for bivariate analyses in matrix notation was as below:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} + \begin{bmatrix} Z_1 & 0 \\ 0 & Z_2 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

Where:

y is the vector of observations, b is the vector of fixed effects, a is the vector of random genetic effects, e is the vector of random residual effect, and X and Z are the incidence matrices relating the observations to the fixed and random genetic effects, respectively.

Heritabilities and genetic correlations between traits were estimated and breeding values for each bird were predicted via the above-mentioned models using WOMBAT software (Meyer, 2007).The reason of using bivariate analysis is to remove the bias from the results because estimates of correlated responses under a univariate animal model are often biased. An adequate mixed-model analysis of correlated changes requires a multivariate approach, in which genetic and environmental variances and covariances, and additive genetic values, are estimated simultaneously (Sorensen *et al.*, 1992). In order to determine genetic trend for each trait through five generations, At the first step, regressions of average breeding values on generation numbers were calculated and then, the average breeding values were drawn across generation numbers. To test the significance of the linear regression equations, analysis of variance approach, at significance level of P<0.05, was utilized.

RESULTS AND DISCUSSION

Descriptive statistics: Pedigree information as well as the descriptive statistics for each trait including number of animals with records, performance means and standard errors are shown in table 1.

Among statistical characteristics of studied traits, the average body weight at 12 weeks of age in West Azerbaijan's native chickens (1335.12 g) was more than native chickens in other country of Iran, such as Yazd (692.05 g), Fars (840.32 g), Mazandaran (885.81g) and Isfahan (1284.57 g) (EmamgholiBegli *et al.*, 2010). In addition, the average egg number during the first 84 days after sexual maturity (35.10)was low and less than indigenous fowls of Yazd (39.74), Mazandaran (38.04) (Hosseini and Tahmoorespur 2013), Fars (53) (Ghazikhani Shad *et al.* 2013) and Isfahan (48) (Yousefi Zonuz *et al.*, 2013). In addition, indigenous fowls of West Azerbaijan had higher mean egg weight (50.53) than native chickens of Yazd (41/61 g), Fars (43/87 g), Mazandaran (47/27g) and Isfahan (47/88 g) (Emamgholi Begli *et al.*, 2010). Finally, the average age at first egg(183.62days) was more than native chickens of Yazd (172.91 days), Mazandaran (160.54 days),Fars (166.64 days) and Isfahan (178.55 days).

Generally, Iranian indigenous chickens are meat–egg type or dual purpose. Growth rate and egg production under conventional rearing system in villages are very low (Ghazikhani Shad *et al.*, 2007). Among them, West Azerbaijan native chickens are heavier (Emamgholi Begli *et al.*, 2010) and become mature in older ages (Hosseini and Tahmoorespur 2013)In comparison with other chickens of other parts of country.These native fowls have been adapted to the corresponding local climatic and environmental conditions through long-term natural selection (Kianimanesh *et al.*, 2001c). In fact, West Azerbaijan province is a mountainous and cold area. Based on meteorological data, average local temperature is 10.5 °C which differs from 9.4 °C in Maku to 11.6 °C in Tekab. According to Bergmann's rule, the populations living in colder climates tend to have larger body sizes than those living in warmer climates. The main theoretical explanation is that a more massive organism has a smaller surface area-to-volume ratio, which helps reduce heat loss (Ryser Fred and Dewey 1985).Based on the study of Camci *et al.* (2002), late sexual maturity would lead to lower total hen-day egg production. Therefore,one of the reasons of low egg number in present study could be due to the delay in sexual maturity.

Heritabilities: Variances components for studied traits are shown in table 2. Also, heritabilities are presented in table 3. Estimates of Heritability for BW12 and EN, MEW and ASM were 0.25±0.08, 0.18±0.05, 0.24±0.03 and 0.43±0.07respectively. However, there are many different estimates for the same trait in different studies. This diversity depends on population size, type, environmental circumstances and method of measuring and analysis (Falconer 1981). Hence, a change in any one of these factors will affect the estimation (Hosseini and Tahmoorespur, 2013).

Heritability for BW12 was moderate and in accordance with the values obtained by Kianimanesh *et al.* (2001a), Niknafs *et al.* (2012), Shadparvar and Enayati (2012), and Salehinasab *et al.* (2013). Although Faruque*et al.* (2013) for non-descript Desi genotype and Yousefi Zonuz *et al.* (2013) for Isfahan native chickens estimated a low heritability, Kamali (1995), Ghorbani (2002), Ghazikhani Shad *et al.* (2013) in Fars native chickens and Faruque *et al.* (2013) inHilly and Naked Neck genotypes, reported much higher values for BW12.Concerning egg number, estimated heritability in present study was in harmony with the findings of Francesh *et al.* (1997), Nikbin (1998), Hartmann *et al.* (2003), Agu*et al.* (2012), and Niknafs *et al.* (2012). However, in a study done by Nurgiartiningsih *et al.* (2002) on two lines of white Leghorn hens, heritability values obtained were 0.05 and 0.18. Mohaghegh Dolatabadi (1999), Kianimanesh *et al.* (2001a) and Shadparvar and Enayati (2012), found lower heritability compared with this study. In contrast, higher values reported by Sabri *et al.* (1999), Oleforuh-Okoleh (2011), Ghazikhani Shad *et al.* (2013), and Wondmeneh *et al.* (2014). Estimated heritability for mean egg weight was close to results reported by Mohaghegh Dolatabadi (1999), Farzin *et al.* (2006) and Niknafs *et al.* (2012). Higher heritability values for this trait were estimated by Sabri *et al.* (1999), Oleforuh-Okoleh (2011), Agu *et al.* (2012), Shadparvar and Enayati (2012), Yousefi Zonuz *et al.* (2013) and Ghazikhani Shad *et al.* (2013). Moreover, by reporting the values ranging from 0.25 to 0.54, for single and group cage chickens, Nurgiartiningsih *et al.* (2005) showed that egg weight is highly heritable. Sang *et al.* (2006) obtained the heritability of egg weight in five different strains of Korean native chickens in the range of 0.22 to 0.43.Ultimately, heritability of age at sexual maturity in current study was relatively highandwithin the range of results reported by Nikbin

(1998), Mohaghegh Dolatabadi (1999), Ghorbani (2002), Niknafs *et al.* (2012), Shadparvar and Enayati (2012), and Ghazikhani Shad *et al.* (2013).A high heritability implies a potentially rapid response to selection (Moss *et al.* 1982).

Genetic correlations: Genetic correlations between studied traits ranged from -0.63 to -0.10 and are presented in table 3.The consequence of having a genetic correlation between traits is a correlated response to selection. A favorable correlation, results in selection for one trait improving another. Conversely, an unfavorable correlation between traits increases the difficulty of making simultaneous improvement in the traits (Cassady and Robison, 2010).

Based on the findings of this study a moderate antagonistic genetic relationship was found between BW12 and ASM. This means that long-term selection for increasing body weight at 12 weeks of age would lead to early sexual maturity in hens. From a physiological point of view, high early growth rate in young chickens would influence the early-completed reproductive system and early sexual maturity (El-Dlebshany 2008). As mentioned before, one of the criteria to select parents of next generation was high performance of BW12 however, against expectations; age at sexual maturity was not shortened after five generations .Hosseini and Tahmoorespur (2013) reported that West Iranian native fowls become sexually mature in older age. Since, reproductive cycle in birds is controlled by changes in day length, and light is responsible for control of ovulation in hens and spermatogenesis in roosters over gonadotrophin releasing hormone, one reason for late maturation in these birds may lie behind the region where these birds belong. West Azerbaijan province is located between 35° 58' and 39° 46' north latitude and day length varies by about 5 hours in comparison with the longest and shortest day of the year. Azerbaijan's native fowls receive less light during the photosensitive phase compared to those at lower latitudes. Accordingly, this trait may have been fixed at this optimum by natural selection.Genetic correlation between EN and ASM was negative and high. This means that Delayed sexual maturation may reduce egg number due to short laying cycle and lower total hen-day egg production (Niknafs *et al.*, 2012). As noted earlier, one reason for low egg number in present study in comparison with Yazd, Isfahan and Mazandaran native fowls may be due to the delay in sexual maturity. Hence, by selecting hens with less age at sexual maturity, egg production will be increased (Shadparvar and Enayati 2012; Ghazikhani Shad *et al.*, 2013).Likewise, similar result was reported by Kianimanesh *et al.*(2001a), Ghorbani (2002), Nwagu *et al.*(2007), Shadparvar and Enayati (2012) and Ghazikhani Shad *et al.*(2013). In the present study, genetic correlation between BW12 and MEW was moderate and positive, which demonstrates the direct relationship between these two traits and suggests that selection based on higher body weight at 12 weeks may increase egg weight. The average body weight at 12 weeks of age as well as mean egg weight in Azerbaijan's native hens was more than other reports on native fowls in other parts of Iran, such as Yazd, Fars, Mazandaran and Isfahan (Emamgholi Begli *et al.* 2010). Evidence obtained by Du Plessis and Erasmus (1972) indicated that larger hens within a bloodline laid larger eggs than those with smaller body weights. Ricklefs (1983) reported that larger body size resulted in large egg length, width and mass, and all factors affect egg weight. Result of this study further corresponds with the reports of Ghazikhani Shad *et al.* (2007) and Ghorbani and Kamali *et al.*(2007). Based on the findings of this study, genetic relationship between BW12 and EN was negative and agreed with the reports of Mohaghegh Dolatabadi (1999) and Niknafs *et al.* (2012). The negative genetic correlation between BW12 and EN suggests that improvement in one trait could have a detrimental effect on other trait. By taking high body weight of Azerbaijan native chickens into consideration, the mean egg number of these birds was less than Yazd, Mazandaran, Fars and Isfahan. As cited above, hens with larger body mass have a tendency to lay larger eggs. Large egg size may stretch and weaken oviductal and cloacal muscles andsometimes can cause severe disorders in hens' reproductive tract such as prolapse and egg binding (Greenacre and Morishita 2015). As a result, egg production is more likely to be adversely affected. This may be an other probable reason for low egg number in West Azerbaijan's native fowl.Finally, genetic correlation between MEW and ASM was estimated negative. This result was in line with the findings of Emamgholi Begli *et al.* (2010), Niknafs *et al.* (2012), and Shadparvar and Enayati (2012). According to Morris (1985), mean egg weight is influenced by the age at which a flock of hens reaches sexual maturity. Camci *et al.* (2002)confirmed that late sexual maturity causes high sexual maturity weight and egg weight.

Genetic Trends: Figures 1 (A-D)illustrates the genetic trends of studied traits as well as linear regression equations. Results obtained from the test of significance of regression coefficients are represented in table 4. The regression coefficients of average breeding values on generations were positive and significant for BW12 and EN, therefore, these two traits showed genetic gain over five generations and MEW as well as ASM responded negatively to genetic improvement.

Concerning age at sexual maturity, one reason for lack of improvement may be due to high concentration on performance of BW12 as the first criteria to select parents of next generation regardless of negative genetic correlation between BW12 and ASM.

Besides, there is a broad consensus that Azerbaijan native chickens, innately, become sexually mature in older ages and it seems any program for improving this trait necessitates more generations to succeed.

High performance of mean egg weigh at 28, 30 and 32 weeks was another criteria that hens were selected as parents of next generation. As mentioned earlier, Azerbaijan native chickens lay heavier eggs in comparison with other chickens of other parts of country. In better words, they have already reached their approximate maximum egg size and efforts to get higher egg weights may not be practical owing to physiological limitations.

Table 1. Pedigree information and the statistics of records related to studied traits.

Summary of Pedigree Structure	BW12	EN	MEW	ASM
Number of "base" animals	488	488	488	488
Number of animals with records	4114	2571	2576	2815
Number of animals with unknown sire	57	48	48	12
Number of animals with unknown dam	2326	1047	1050	1020
Number of sires with progeny records	115	72	72	79
Number of dams with progeny records	741	463	464	507
Mean	1335.12	35.10	50.53	183.62
SD	195.83	11.41	3.58	15.41
Min	800	8	37.1	133
Max	1870	70	64.8	233

BW12: Body Weight at week 12, EN: Egg Number, MEW: Mean Egg Weight at 28, 30 and 32 weeks and ASM: Age at Sexual Maturity

Table 2.variance components of studied traits

Traits	σ_A^2	σ_E^2	σ_P^2
BW12 (g)	1586.25	4758.4	6344.65
EN	19.52	88.85	108.37
MEW (g)	3.12	9.85	12.97
ASM (day)	87.75	116.14	203.89

BW12: Body Weight at week 12, EN: Egg Number, MEW: Mean Egg Weight at 28, 30 and 32 weeks and ASM: Age at Sexual Maturity

Table 3.Heritabilities (diagonal), Genetic (above diagonal) and Phenotype (below diagonal) Correlations with their standard errors.

Traits	**BW12**	**EN**	**MEW**	**ASM**
BW12	0.25±0.08	-0.14 ± 0.01	0.25± 0.04	-0.32± 0.08
EN	0.15±0.03	0.18±0.05	-0.10± 0.01	-0.63± 0.02
MEW	0.12±0.03	-0.11±0.03	0.24±0.03	0.30± 0.06
ASM	-0.15±0.06	-0.46±0.05	0.10±0.07	0.43±0.07

BW12: Body Weight at week 12, EN: Egg Number, MEW: Mean Egg Weight at 28, 30 and 32 weeks and ASM: Age at Sexual Maturity

Table 4.Parameters of linear regression equations.

Parameter	**BW12**	**EN**	**MEW**	**ASM**
Regression Coefficient	2.37**	0.17**	-0.0053^{ns}	-0.033^{ns}
Intercept	-3.45	-0.20	0.010	-0.21

Levels of significance: ns (not significant): $p \geq 0.05^{ns}$, $p<0.05$*, $p<0.01$**

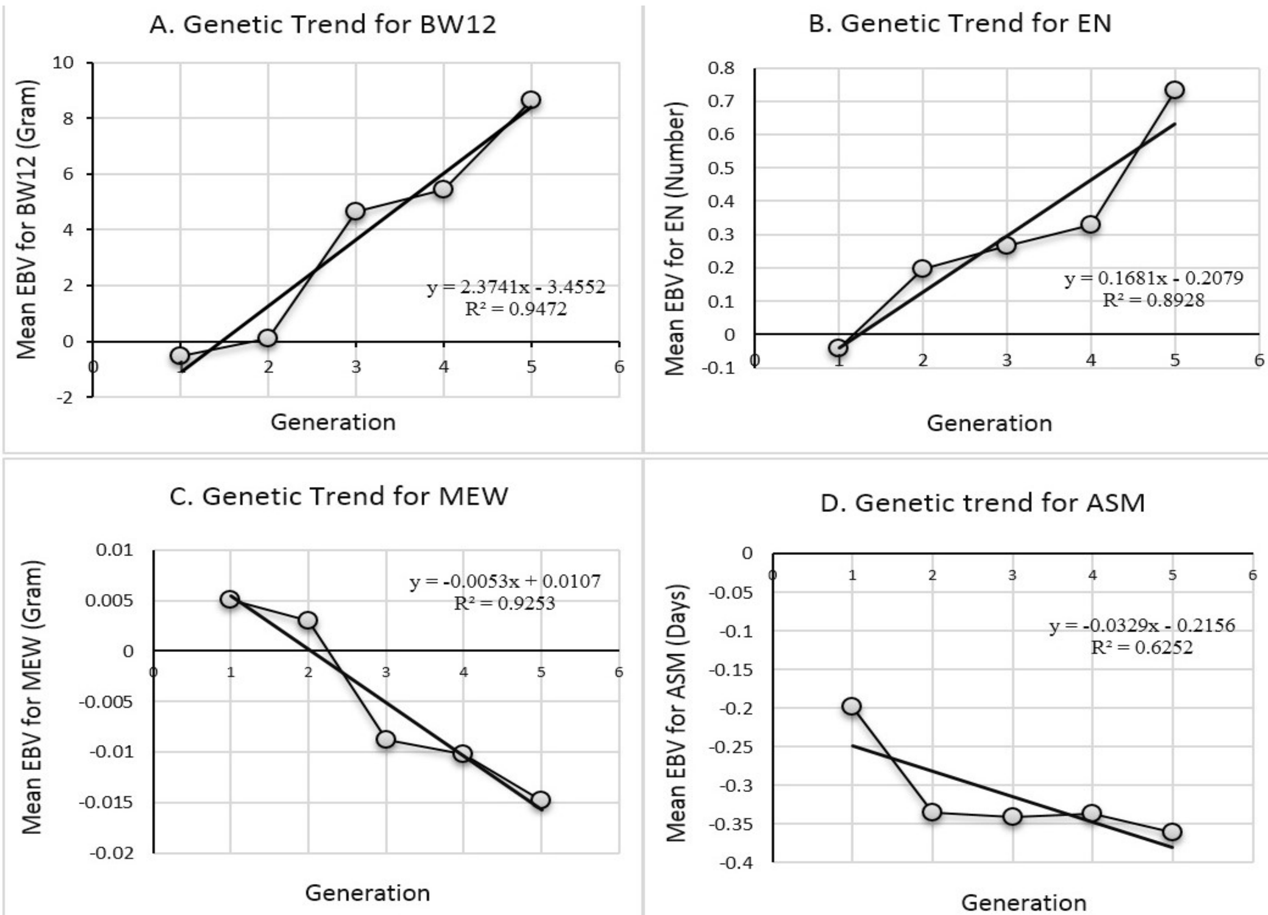

Figure 1.: Genetic trend for (A) Body Weight at week 12 (BW12), (B) Total number of eggs laid during the first 12 weeks after flock maturity (EN), (C) Mean Egg Weight at 28, 30 and 32 weeks (MEW)and (D) Age at Sexual Maturity (ASM) through 5 generations of selection.

Conclusion: This study considered genetic parameters such as heritabilities and genetic correlations as well as genetic trends between growth and egg production traits in West Azerbaijan native fowls to evaluate genetic improvement over five selected generations.

Results of this study, reveals that all investigated traits had a relatively moderate heritability.MEW had a positive genetic relationship with ASM and BW12.Nonetheless,other traits possessed negative genetic correlation with each other. Among the studied traits, BW12 and EN performed significantly ($p<0.05$) better than the base population. In better words, these two traits showed genetic gain over five generations. Genetic progress indicates that the breeding programs have been effective and genetic selection based on better breeding values would be conducive to encouraging resultants.

Studied chickens were indigenous to West Azerbaijan province and most of the rural farmers and village households keep at least a few chickens for both meat and egg production. Therefore, it is highly recommended that selection criteria include both growth and reproductive traits simultaneously. It is of the paramount importance that incase of simultaneous selection for improving different traits, interaction between traits should be taken into account.

Based on findings of this study, West Azerbaijan native fowls had larger body size and genetically, good potential for meat production, nevertheless, total number of eggs laid during laying period was low and require more consideration. As regards high and negative genetic correlation between ASM and EN, by selecting hens with less age at sexual maturity egg production will likely to be increased.

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